Variation of a Lightning NO_x Indicator for National Climate Assessment

William Koshak[1] , B. Vant-Hull[2], E. W. McCaul[3], and H. S. Peterson[3]

[1]Earth Science Office, NASA Marshall Space Flight Center, Huntsville, AL USA.
[2] Steinman Hall, City College of New York, New York, NY, USA
[3]Universities Space Research Association, National Space Science & Technology Center, Huntsville, AL, USA.

1. INTRODUCTION

Lightning nitrogen oxides (LNOx) indirectly influences our climate since these molecules are important in controlling the concentration of ozone (O_3) and hydroxyl radicals (OH) in the atmosphere [Huntrieser et al., 1998]. In support of the National Climate Assessment (NCA) program, satellite Lightning Imaging Sensor (LIS; Christian et al. [1999]; Cecil et al. [2014]) data is used to estimate LNOx production over the southern portion of the conterminous US for the 16 year period 1998-2013.

2. METHODOLOGY

LIS measures a small fraction of flash energy from k^{th} flash:

$$\beta_k = \frac{Q_k}{E_k} = \frac{\text{LIS-detected Flash Optical Energy}}{\text{Total Energy of the Flash}}$$

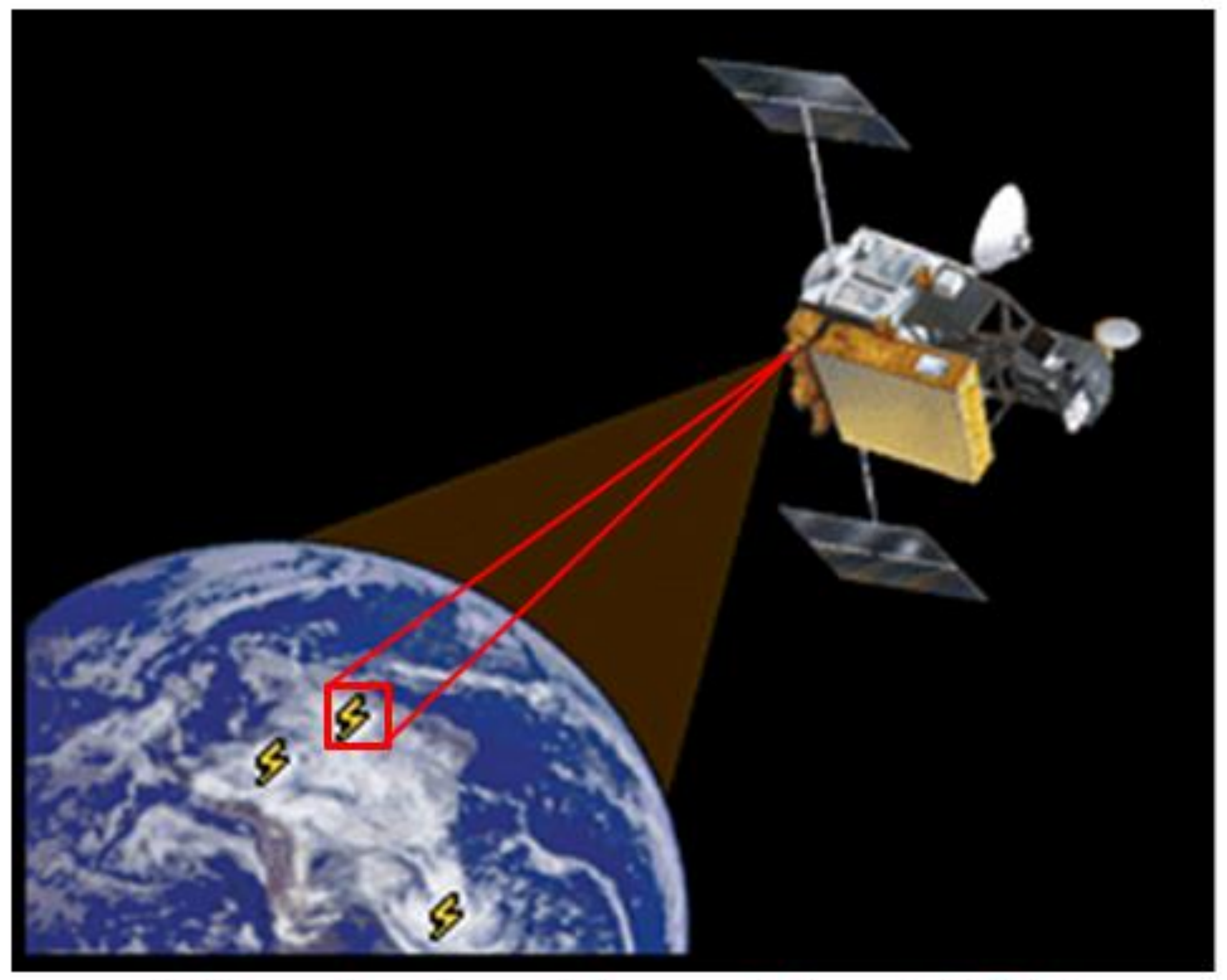
Flash LNOx Production:

$$P_k = \frac{Y}{N_A} E_k = \frac{Y}{N_A}\frac{Q_k}{\beta_k} \sim \frac{Y}{N_A}\frac{Q_k}{\beta}$$

Yield: $Y \sim 10^{17}$ *molecules / J*

Fraction: $\beta \sim 1.87\times10^{-19}$

N_A = Avogadro's constant



LIS shown detecting optical energy Q_k from the k^{th} flash.

Total LNOx Production P_t in a Region:

(Sum over all N_o observed flashes & account for LIS detection efficiency and viewtime to extrapolate to total # flashes N_t)

$$P_t = \sum_{k=1}^{N_o} P_k + (N_t - N_o)\left(\frac{1}{N_o}\sum_{k=1}^{N_o} P_k\right)$$

Ancillary Details

$$Q_k = CA\Delta\lambda \sum_{i=1}^{m_k}\sum_{j=1}^{n_k}\left[\frac{a_{jk}\cos\alpha_{jk}}{r_{jk}^2}\right]\bar{\xi}_{\lambda ijk} = \text{ LIS-detected optical energy of kth flash}$$

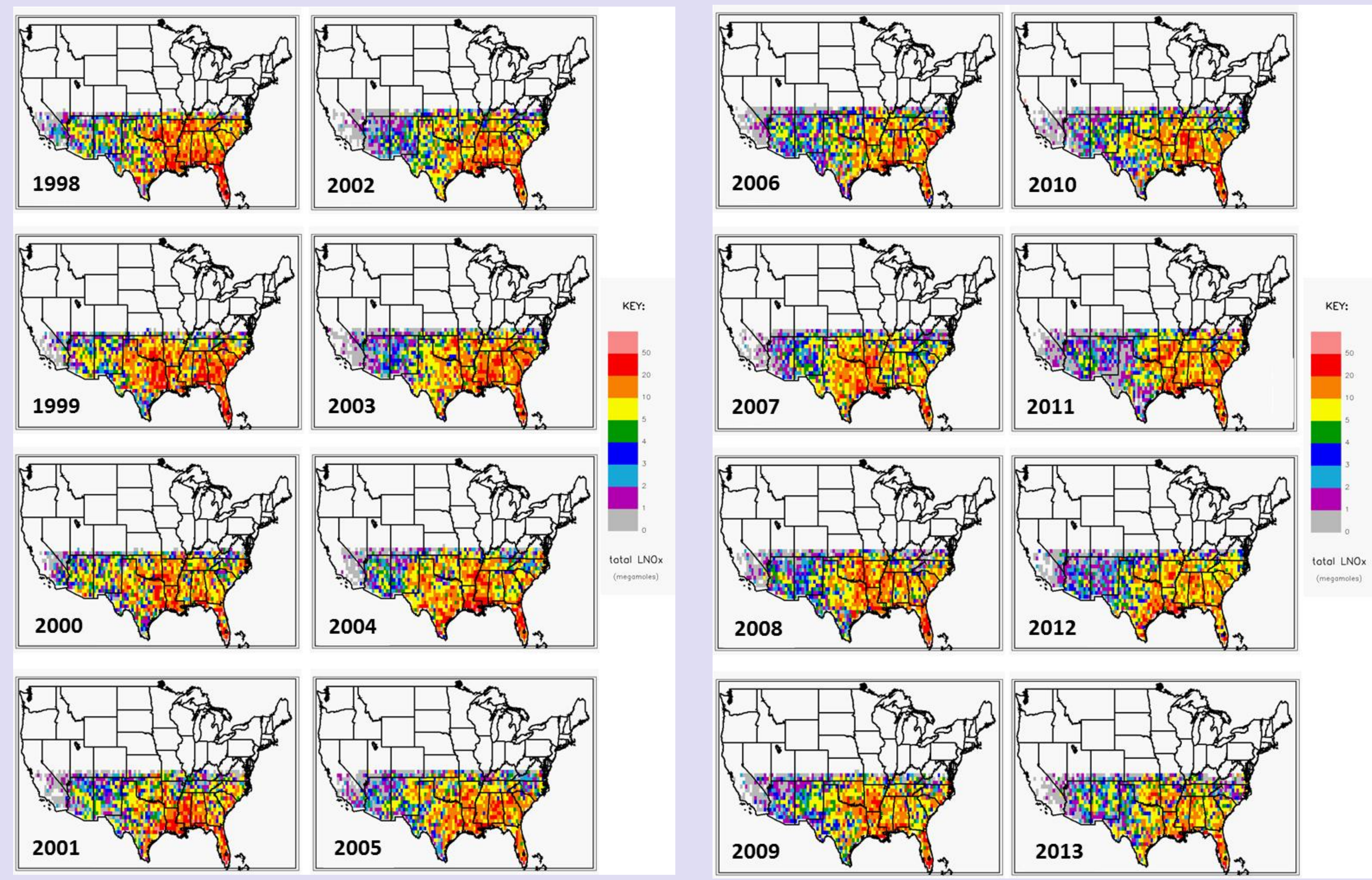
$$\alpha_{jk} = \sin^{-1}\left[\left(\frac{R+z}{R+H}\right)\sin\theta_{jk}\right] = \text{foreshortening angle}$$

$$r_{jk} = (R+H)\frac{\sin(\alpha_{jk}-\theta_{jk})}{\sin\theta_{jk}} = \text{range (from event footprint to LIS)}$$

R = Earth Radius, z = LIS orbital altitude, θ_{jk} = event boresight angle, C = conversion factor, A = LIS entrance aperture area, $\Delta\lambda$ = LIS bandwidth, $\bar{\xi}_{\lambda ijk}$ = event energy density, m_k = # frames occupied by kth flash, n_k = # pixels illuminated by kth flash.

3. ANNUAL GEOGRAPHICAL VARIATIONS

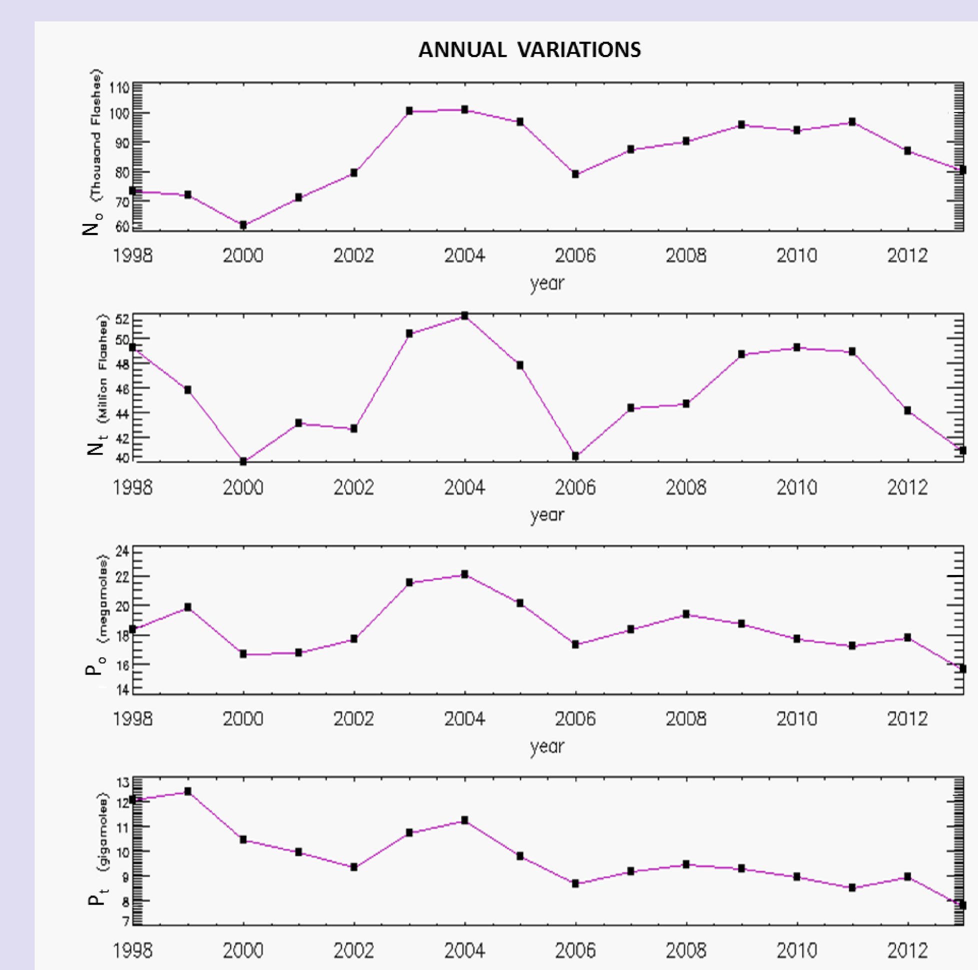
Below is the annual geographical variations of the total LNOx production P_t described in the previous section. The value of beta has been calibrated so that the mean LNOx production per flash in 1998 (the reference year) is 250 moles.



4. LNOx TREND

The trend in the total LNOx (summed up across the entire southern CONUS region) and associated flash counts are provided here. Keeping in mind that LIS is regarded as a very stable instrument [Buechler et al., 2014], note that there is a downward trend in the LIS-inferred total LNOx production.

Downward Trend in LNOx



5. REFERENCES

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